nature reviews disease primers

https://doi.org/10.1038/s41572-025-00631-4

Primer

Check for updates

Groin hernia

Jacob Rosenberg [1] ✉, Sarfaraz Baig [2], David C. Chen [3] & Joep Derikx [4]

Abstract

Groin hernias are among the most common indications for surgery worldwide, affecting both men and women, with a significantly higher prevalence in men. These hernias occur when intra-abdominal contents protrude through a weakened area in the groin region, most commonly as inguinal or femoral hernias. The pathogenesis of groin hernias is a complex interplay of genetic predisposition, connective tissue abnormalities and mechanical strain. While watchful waiting is an option for some asymptomatic patients, surgical repair remains the definitive treatment, with both open and minimally invasive techniques available. Tension-free mesh repair has significantly reduced the overall recurrence rates and is now the standard approach in adults in most clinics. However, tissue-based repairs are still preferred in select populations such as children, teenagers and those in resource-limited settings. Advances in laparoscopic and robotic-assisted techniques offer benefits such as reduced postoperative pain and faster recovery. Despite surgical advancements, complications, such as chronic postoperative pain and recurrence, continue to pose challenges. Future research aims to refine surgical techniques, look at mesh-related complications, develop bioengineered meshes and explore the genetic basis of hernia formation.

Sections

Introduction

Epidemiology

Mechanisms/pathophysiology

Diagnosis, screening and prevention

Management

Quality of life

Outlook

[1]Department of Surgery, Herlev Hospital, University of Copenhagen, Copenhagen, Denmark. [2]Digestive Surgery Clinic, Belle Vue Hospital, Kolkata, India. [3]Lichtenstein Amid Hernia Clinic at UCLA, Santa Monica, CA, USA. [4]Department of Paediatric Surgery, Amsterdam UMC, University of Amsterdam, Amsterdam, The Netherlands. ✉e-mail: jacob.rosenberg@regionh.dk

SHOUT
SHARE
IT

Introduction

Groin hernias are a common condition, especially in men, that occurs with similar frequency across different races and regions of the world. A groin hernia is characterized by the protrusion of abdominal contents, such as parts of the intestine or omentum, through an opening in the abdominal wall in the groin region. The most frequent type of groin hernia involves the inguinal canal, a passageway in the lower abdomen that contains blood vessels and the spermatic cord in men or the round ligament in women (Fig. 1). Inguinal hernias can be further categorized as direct or indirect. Direct inguinal hernias occur when abdominal contents push through a weak spot in the muscle wall, above the inguinal ligament and medial to the inferior epigastric vessels. Indirect inguinal hernias arise when abdominal contents pass through the inguinal canal, lateral to the inferior epigastric vessels[1,2]. Hence, direct inguinal hernias are also known as medial inguinal hernias, while indirect hernias are referred to as lateral inguinal hernias.

Femoral and obturator hernias are also classified as groin hernias. A femoral hernia forms when abdominal contents push through the femoral canal, which carries the femoral artery, vein and nerve below the inguinal ligament. These hernias are more common in women than in men and are often mistaken for inguinal hernias. Of note, femoral hernias pose a greater risk of strangulation, where blood flow to the herniated tissue is cut off, leading to tissue death[1,3]. The rarest form, the obturator hernia, occurs when abdominal contents push through the obturator canal in the pelvis, which contains the obturator nerve and vessels. Like femoral hernias, obturator hernias are more common in women and are frequently misdiagnosed due to the absence of a visible groin bulge[4]. The current definition of groin hernias also includes the presence of a lipoma in the inguinal canal as it can produce the same symptoms as herniated bowel or intra-abdominal fat, and the removal of the lipoma can alleviate these symptoms[5].

Both inguinal and femoral hernias usually present as a noticeable lump or swelling in the groin, which becomes more prominent when coughing, straining or standing upright[6]. These hernias can cause discomfort, pain or a sensation of pressure and, if left untreated, may lead to serious complications such as strangulation, where the blood supply to the herniated tissue is compromised, necessitating emergency surgery. Presentation can differ in women compared with men and be hard to diagnose since a lump in the groin is not always present as clearly as in men.

Groin hernias develop from a combination of anatomical weaknesses, increased intra-abdominal pressure and connective tissue abnormalities, with several risk factors involved, including age, male sex, family history, chronic cough, strenuous physical labour and pregnancy[1,7]. Men are more susceptible to inguinal hernias, whereas women face a greater risk of femoral hernias and the associated complications.

A hernia is classified as reducible when its protruded contents can be repositioned into the abdominal cavity. If reduction is not possible, the hernia is termed irreducible or incarcerated. Strangulation refers to the compromise of vascular supply to the herniated contents, potentially leading to ischaemia and tissue necrosis[6]. Incarceration is not the primary concern for patients with hernias; mortality rates are very low, yet hernias decrease the quality of life for those affected, and this is by far the most important outcome measure in hernia surgery[8].

Hernias never disappear without intervention but instead tend to continuously grow. Several techniques are employed to repair groin hernias, including both mesh and non-mesh methods. A mesh is a medical device used to reinforce the weakened or defective area of the abdominal wall through which the hernia has protruded. Most commonly, it is made from synthetic materials such as polypropylene or polyester, though biological meshes derived from human or animal tissue are also available. Mesh repairs are favoured for their lower recurrence rates[9]. All groin hernia repairs aim to reduce the hernia back into the abdominal cavity and secure the defect using either sutures alone, trusting the permanent strength of the scar induced, or a synthetic mesh that will integrate into the abdominal wall. However, complications such as infection (mainly in open repairs), mesh migration and shrinkage can arise. Non-mesh repairs are more commonly used in children, adolescents and patients with a history of mesh-related complications[10,11]. This Primer provides an overview of groin hernia epidemiology, pathophysiology, diagnosis, screening, prevention, management strategies, paediatric considerations, and impact on quality of life as well as an outlook of potential future developments in the field.

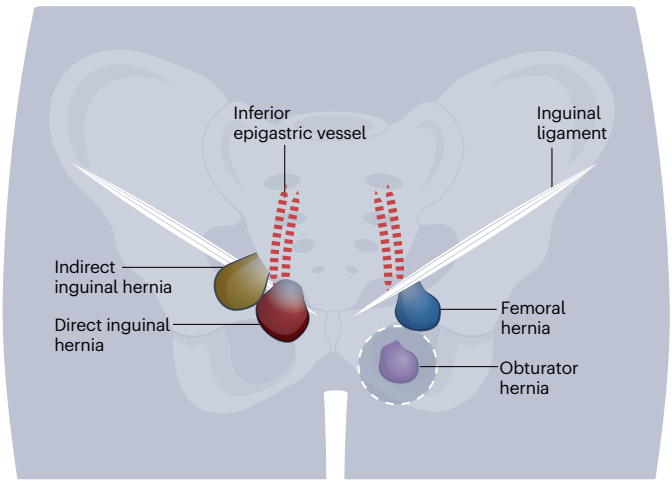

Fig. 1 | Typical location of the different types of hernias in the groin region and associated anatomical landmarks. Direct and indirect hernias are placed cranial to the inguinal ligament and the femoral hernia is placed below the inguinal ligament. Direct hernias are placed medial to and indirect hernias lateral to the inferior epigastric vessels. All groin hernia types can affect both men and women, but femoral and obturator hernias are more often seen in women than in men and direct hernias are more often seen in men than in women. The drawing of an obturator hernia with a dashed line indicates that there is no visible bulge.

Epidemiology

Incidence and prevalence

The overall lifetime prevalence of groin hernias has been reported as 24% in population-based studies[12,13]. While groin hernias are relatively rare in women, with a lifetime risk of 3–6%, men face a much higher lifetime risk of 27–43%[14–18].

The most common subtypes of groin hernia are indirect inguinal, direct inguinal and femoral hernias. Other rare types include obturator, supravesical and parainguinal hernias. Indirect inguinal hernias are the most common subtype in both sexes. In women, femoral hernias are the second most common, followed by direct and pantaloon hernias, with the latter referring to both direct and indirect inguinal hernias existing together. In men, direct hernias are more common than femoral hernias, with pantaloon hernias also occurring frequently[19]. The following prevalence rates are cited for the subtypes of primary abdominal hernias: inguinal hernias, 70–75%; femoral hernias, 6–17%; umbilical

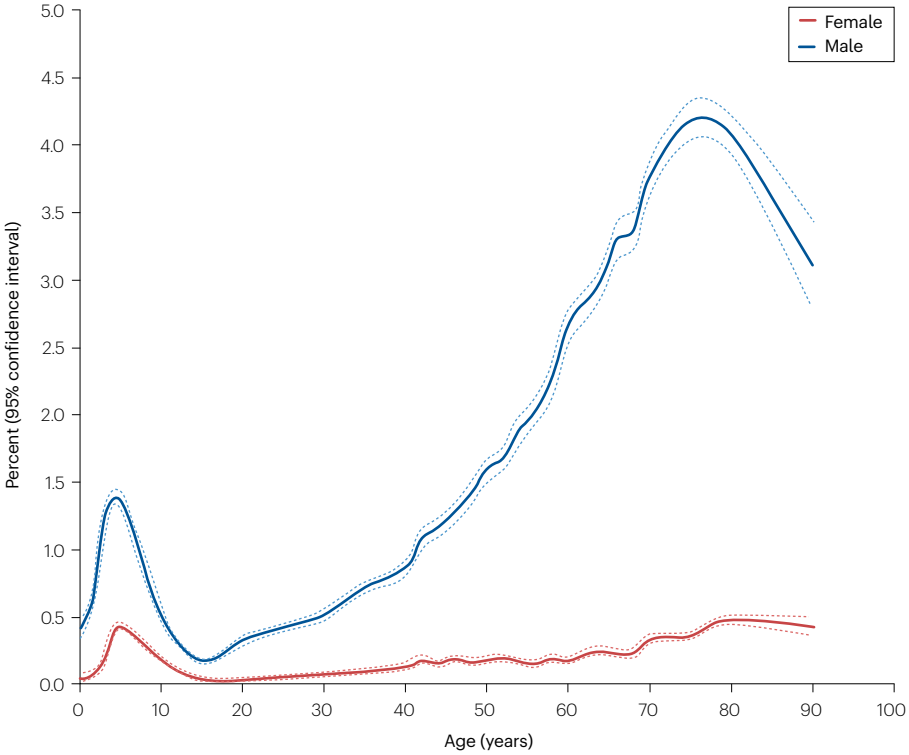

Fig. 2 | Prevalence of groin hernia repair, inguinal hernia and femoral hernia combined, stratified by age and sex. The results indicate the percentage of persons at a given age in the population who were operated for a groin hernia during the study period. Example: 4.19% of all men aged 75–80 years were operated for a groin hernia at least once during the study period. The dotted lines represent 95% confidence intervals. Reprinted from ref. 17, CC BY 4.0.

hernias, 3–8.5%; and uncommon variants, 1–2%[6,20]. A single centre from the UK indicated a similar prevalence order amongst groin hernia[21].

Even in women, the total number of detected inguinal hernias is greater than that of femoral hernias, most often presenting as an indirect hernia. Still, 75% of femoral hernias occur in women, whereas 90% of the inguinal hernias occur in men. Thus, inguinal hernias are significantly more common in men, with reported male-to-female ratios ranging from 8:1 to 20:1 in various studies[22]. During fetal development, testicles descend from the abdomen to the scrotum in men, leaving a potential persisting canal in some individuals[23].

Inguinal hernias occur in 5% of term infants and 10% of preterm infants[24]. The cumulative incidence of childhood inguinal hernias is estimated to be approximately 7% in male individuals, with the highest occurrence under the age of 1 year. In female individuals, the incidence is about 1%, peaking at the age of 5 years[24]. The risk of incarceration is 7% in all paediatric cases, with 11% in preterm children, necessitating surgical repair in nearly all instances[25].

Inguinal hernia repairs follow a bimodal distribution, with peaks in early childhood (around 5 years of age) and again between 70 and 80 years in both sexes[18,22,26,27] (Fig. 2). Among men under 40 years, 20% of inguinal hernias are direct, but this figure increases to over 40% in those over 60 years, indicating a higher incidence of direct hernias with age[28]. This trend may be related to age-associated degradation of elastic fibres, particularly around the deep inguinal ring[26]. The prevalence of groin hernia repairs varies geographically. Annual repair rates range from 17–86 per 100,000 population in sub-Saharan Africa[29–31], to 140–240 per 100,000 in the European Union[32] and 275 per 100,000 in the USA[33]. These figures may not reflect true prevalence in low-resource settings, where there is often a lower rate of access to health care to initially diagnose hernia and an unmet need for surgery.

Risk factors

Risk factors for inguinal hernia include male sex, prematurity, advanced age, patent processus vaginalis, systemic connective tissue disorders and low BMI[34,35]. Contributing factors can be congenital (for example, incomplete closure of the processus vaginalis or collagen defects), acquired (for example, chronic coughing, heavy lifting, previous surgeries) or systemic (for example, ageing)[34].

Smoking, counterintuitively, appears to decrease the risk of developing groin hernias (but increases the risk for recurrence), according to a population-based cohort study[36]. Likewise, obesity is associated with a reduced risk[12,22,37–39], even though one might expect the opposite given the increased intra-abdominal pressure in patients with obesity. Some researchers propose that this phenomenon may stem from obesity reducing the detection of hernias or mitigating them by 'blunting' the inguinal canal with fat[36]. Interestingly, high intra-abdominal pressure, observed with cumulative exposure to heavy physical activity, chronic cough, ascites, peritoneal dialysis or ventriculoperitoneal shunt placement, raises the risk for lateral inguinal hernias but not for medial hernias[7,34,35]. Coughing and vomiting may exert the highest type of pressure on the abdominal wall[40], more than physical labour, and some patients can tell that the hernia became apparent from a single cough or vomiting episode.

Collagen disorders are linked to the formation of groin hernias as there is a strong association with Ehlers–Danlos syndrome[38] and a weak association with abdominal aneurysms and thoracic aortic disease[41,42]. Surgeries such as prostatectomy[43] and appendectomy[44] have been implicated in the aetiopathogenesis of groin hernias probably due to trauma-induced neuromuscular weakening. A family history of groin hernias (in parents or siblings) increases the risk of their development[45,46] although the genetic basis is not fully conclusive. Twin

studies have produced conflicting results regarding groin hernia[47,48]. While familial awareness may contribute to earlier detection, genetic inheritance likely plays a role, though it is not a straightforward recessive or dominant pattern, and the patterns of inheritance remain unclear[49]. In 2022, a meta-analysis of genome-wide association studies identified 63 loci contributing to inguinal hernia risk, some of which are specific to sex and ancestry[50]. Another systematic review found 5 studies reporting a genetic predisposition for primary inguinal hernia, identifying 92 susceptible loci across 66 genes primarily associated with immune responses[51].

The relationship between physical activity and groin hernia is debated. While some studies suggest that strenuous activity is a risk factor[50,52,53], others do not[22]. In 2012, a registry study found an association between increased physical activity and indirect inguinal hernias but not direct hernias[54], possibly explaining the conflicting results as pooling of direct and indirect hernias may lead to misinterpretation of data. In 2017, another study showed that approximately 30% of first-time lateral inguinal hernia repairs in men with high occupational mechanical exposure could be preventable if time spent standing was reduced to less than 6 hours per day and time walking was reduced to less than 4 hours per day[7]. Interestingly, the study found an association between strenuous work and the development of lateral hernias but not medial hernias. Both chronic constipation and chronic obstructive pulmonary disease increase intra-abdominal pressure, which would suggest a higher hernia prevalence. However, only a weak positive association with these conditions was found[46,54,55].

Mortality

While mortality from groin hernia itself is rare, it increases with strangulation[6]. A systematic review indicates that emergency hernia repairs have a 30-day mortality rate of 0–11.8%, compared with 0–1.7% for elective repairs, representing a 26-fold increase[56]. When bowel resection is performed, the mortality rate rises to 7.9%. This indicates that groin hernia surgery should preferably be conducted in elective settings before any complications arise.

Mechanisms/pathophysiology

The paired muscles and associated aponeuroses and fascia of the anterior abdominal wall are divided into the anterolateral (external oblique, internal oblique and transversus abdominis) and midline (rectus abdominis and pyramidal) muscles. These muscles serve various functions, including protecting the viscera and preventing them from protruding through the abdominal wall[34,57]. However, weak points in the anterior abdominal wall can lead to congenital, acquired or combined hernias.

Inguinal hernia development

Inguinal hernias may originate from the persistence of a processus vaginalis (leading to indirect, so-called lateral inguinal hernia) or from a cranialized medial insertion of the transversus abdominis muscle (leading to direct/medial inguinal hernia, or both). The processus vaginalis forms during testicular descent as a protrusion of the peritoneum and should normally obliterate early in life[34,57]. The persistence of this structure is strongly correlated with the development of indirect inguinal hernia[57]. The inguinal canal begins at the internal (deep) inguinal ring as an invagination of the processus vaginalis through the transversalis fascia. It ends at the external (superficial) inguinal ring, where the processus vaginalis exits the abdominal wall through the aponeurosis of the external oblique muscle[57]. In men, the inguinal canal contains the spermatic cord, while in women it contains the round ligament. The high incidence of inguinal hernias in humans may be explained by evolutionary changes in the abdominal wall, which originally supported the body on four limbs. As humans adopted bipedalism, the groin area may not have fully adapted to the increased demands of an upright posture[34,58].

Femoral and obturator hernias

The femoral canal connects the pelvic cavity to the anteromedial thigh through the femoral ring. It is bounded by the femoral vein laterally, the lacunar ligament medially, the inguinal ligament anteriorly, and the pectineal ligament posteriorly. Normally, the femoral canal contains lymph nodes, connective tissue and fat. A femoral hernia passes through the femoral ring beneath the inguinal ligament and through the femoral canal to emerge at the saphenous opening (fossa ovalis)[57].

The obturator foramen is formed by the rami of the ischial and pubic bones on the anterolateral pelvic wall. It is almost entirely closed by the obturator membrane, except for a small opening (the obturator canal), through which the obturator nerve, artery and vein pass[59]. Obturator hernia formation occurs in three stages: preperitoneal fat enters the obturator canal, forming a fat plug; peritoneal dimpling into the fat plug leads to hernia sac formation; and intraperitoneal organs, usually the ileum, herniate into the sac[59].

Loss of structural integrity at the musculo-tendinous layer

All types of primary groin hernias are associated with collagen subtype imbalances, which lead to altered extracellular matrix (ECM) composition and degradation[34,51]. For recurrent hernias, there may be inadequate scar formation from the primary repair. ECM proteins in the connective tissue of the abdominal wall provide mechanical strength and help prevent hernia formation. Collagen, the major component of the ECM, consists of several types: type I collagen (thick, strong fibres found throughout the body, including fascia, skin and ligaments, and is the primary collagen type in mature wounds), type III collagen (thinner than type I, found in smaller amounts and primarily involved in early wound healing) and type IV collagen (the main collagen type in the basement membrane)[34,51].

Matrix metalloproteinases (MMPs) are enzymes responsible for degrading collagen and maintaining its homeostasis and remodelling. Their activity is regulated by endogenous inhibitors like tissue inhibitors of metalloproteinases (TIMPs)[34,51]. Two recent systematic reviews of circulating biomarkers for abdominal wall hernias identified MMP2 as the most studied biomarker for inguinal hernias. MMP2 levels are elevated in patients with clinically detectable hernias, especially in those with medial inguinal hernias[34,51]. Circulating markers for type I collagen and the type I-to-type III collagen ratio, such as lysyl oxidase and MMPs, are reduced, while markers for type IV collagen synthesis and turnover are increased in patients with inguinal hernias compared with controls[34,51]. However, the causal relationship between altered MMP and collagen levels with abdominal wall hernia development remains unclear. Tissue studies of patients with lateral inguinal hernias show higher MMP2 protein levels in the fascia transversalis than in patients with medial or no inguinal hernias[34,51]. TIMP2 levels are decreased in patients with lateral inguinal hernias compared with those with medial hernias or controls[51]. In adult patients with inguinal hernias, an increase in type III collagen in skin fibroblasts and a decreased type I-to-type III collagen ratio in the fascia transversalis, hernia sac, and skin have been observed compared with healthy volunteers[34,51].

Diagnosis, screening and prevention

Signs and symptoms

Hernias are commonly identified by the presence of a lump that may be reducible or incarcerated. In cases of a reducible hernia, patients might not exhibit symptoms and may only seek medical advice because their partner discovered the hernia. When the lump causes discomfort during physical activities, such as sports or sexual activity, patients may have been referred to a surgeon. In some instances, the hernia itself can cause pain, which is frequently the primary reason for seeking surgical intervention, and in some cases, especially in women with femoral hernias, symptoms are classical, such as pain or discomfort, but there is not a visible or palpable lump at clinical examination.

Pre-operative pain is an important factor that demands surgical attention as its intensity across hernia types correlates with chronic postoperative pain[60,61]. However, this does not suggest that patients with pre-operative pain should avoid surgery. Rather, it is important to consider the broad differential of groin pain coexisting with hernia and is crucial to inform patients about the increased risk of chronic pain following the procedure.

Diagnosing an inguinal hernia is often straightforward. Patients typically present with a groin lump that may be visible during daily activities but disappears when lying down. Distinguishing between direct and indirect inguinal hernias pre-operatively is challenging and generally unnecessary since the treatment for both involves surgical repair with mesh in adult patients[6]. Intra-operatively, every patient will receive prosthetic mesh reinforcement; however, the dissection and preparatory steps for mesh placement differ slightly according to the specific hernia subtype. These procedural nuances are routinely understood by experienced surgeons and therefore do not necessitate additional pre-operative diagnostic evaluation.

It has been suggested that indirect hernias in young men up to 29 years old may be treated without mesh with favourable results[62,63]. Consequently, pre-operative differentiation between direct and indirect hernias may become more relevant in the future as young men with indirect hernias might undergo open repair without mesh, while a laparoscopic approach would be more suitable for direct hernias. However, these findings need confirmation from randomized trials or registry trials with long-term follow-up. Until then, the standard recommendation remains that it is not necessary to differentiate between direct and indirect hernias pre-operatively for adult patients as mesh repair is typically indicated for both types[64].

Incarceration and strangulation. An incarcerated inguinal hernia refers to one that cannot be reduced into the abdomen, posing an increased risk of strangulation if left untreated without reduction via surgical repair. Some patients may present with a long-standing incarcerated hernia that has not led to complications, in which case, the risk of strangulation may not be significant and surgery is not immediately required. In cases without signs of compromise or complication, it is acceptable for a primary care physician or surgeon to attempt manual reduction with a higher likelihood of success than the patient attempting self-reduction[64]. Clinical symptoms of an incarcerated hernia may range from no symptoms to abdominal pain and intestinal obstruction (ileus) resulting from an obstructed bowel. Incarcerated hernias are often considered a contraindication for laparoscopic repair due to the increased risk of bowel perforation during attempts at reduction[65]. Consequently, open repair is commonly recommended. Nevertheless, experienced minimally invasive surgeons may opt for laparoscopic or robotic repair in emergency settings, often with excellent results[66]. The advantage of a laparoscopic approach is the possibility of inspecting an incarcerated bowel loop in the abdomen.

Strangulation represents a serious, life-threatening complication of hernia disease, and there is typically local pain and, in more advanced cases, there may be skin changes with erythema/redness, oedema and sepsis-induced fever[67]. Strangulation occurs when the blood supply to the herniated tissue is compromised (Fig. 3), necessitating immediate surgical intervention. Initially, venous return is compromised, leading to oedema due to lymphatic and capillary swelling with fluid shifting to the interstitial space[68,69]. This process further compromises blood supply as the arterial blood flow occludes, resulting in ischaemic changes to the herniated contents. In severe cases, particularly if the hernia contains bowel or viscera, ischaemia and subsequent perforation can lead to sepsis, a critical condition requiring urgent surgery[70].

Occult hernias with classic symptoms but no lump. One of the diagnostic challenges arises when a patient presents with typical hernia symptoms, such as pain and discomfort in the groin area, but without a visible lump. This scenario can be seen in some women with a femoral hernia. Moreover, it is often seen in patients with obesity, where palpation may be difficult, but can also occur in individuals with a lean build. In such cases, the patient may report the presence of a lump during physical exertion that cannot be reproduced during physical examination. Imaging techniques, such as dynamic ultrasound or CT scans, are usually recommended to confirm the diagnosis in these cases[71].

Femoral hernias. A typical femoral hernia presents as either discomfort or pain in the groin accompanied by a lump or, in more severe cases, as an ileus with or without strangulation. The narrow hernia defect in femoral hernias increases the likelihood of incarceration[72].

Differentiating between femoral and inguinal hernias can be challenging, especially in patients with obesity. The two types of hernias are distinguished based on their location relative to the inguinal ligament. The inguinal ligament is identified by palpating the anterior superior iliac spine and the pubic tubercle[73]. Inguinal hernias are located above the inguinal ligament, whereas femoral hernias are below it (Fig. 1).

Obturator hernias. Obturator hernias are rare and difficult to diagnose. They are most frequently identified in the acute phase when they cause bowel obstruction due to incarceration of bowel through the obturator foramen. Bowel obstruction was found to be present in 94% of obturator hernia cases, with 85% of patients experiencing abdominal pain[74]. However, only half of these patients presented with the Howship–Romberg sign, a combination of inner thigh pain, paraesthesia and an inability to adduct the thigh[75].

Paediatric groin hernia. In children, inguinal hernias typically manifest as a lump in the groin, scrotum or labia majora, which bulges when the child coughs or cries[76]. Paediatric groin hernias are usually diagnosed clinically based on physical examination, with the parent or doctor palpating the lump. In instances where a clinical hernia is not evident, a history from the parents may suffice for diagnosis.

In children under 2 years of age, an inguinal hernia should be considered if the child is crying without any obvious cause[77]. Although hernias are not necessarily painful unless incarcerated or strangulated, prompt diagnosis is essential to avoid complications[77]. If a hernia is suspected, immediate efforts to manually reduce the hernia should be made, often with the child placed in the Trendelenburg position[78]. If manual reduction is unsuccessful, sedation and analgesia,

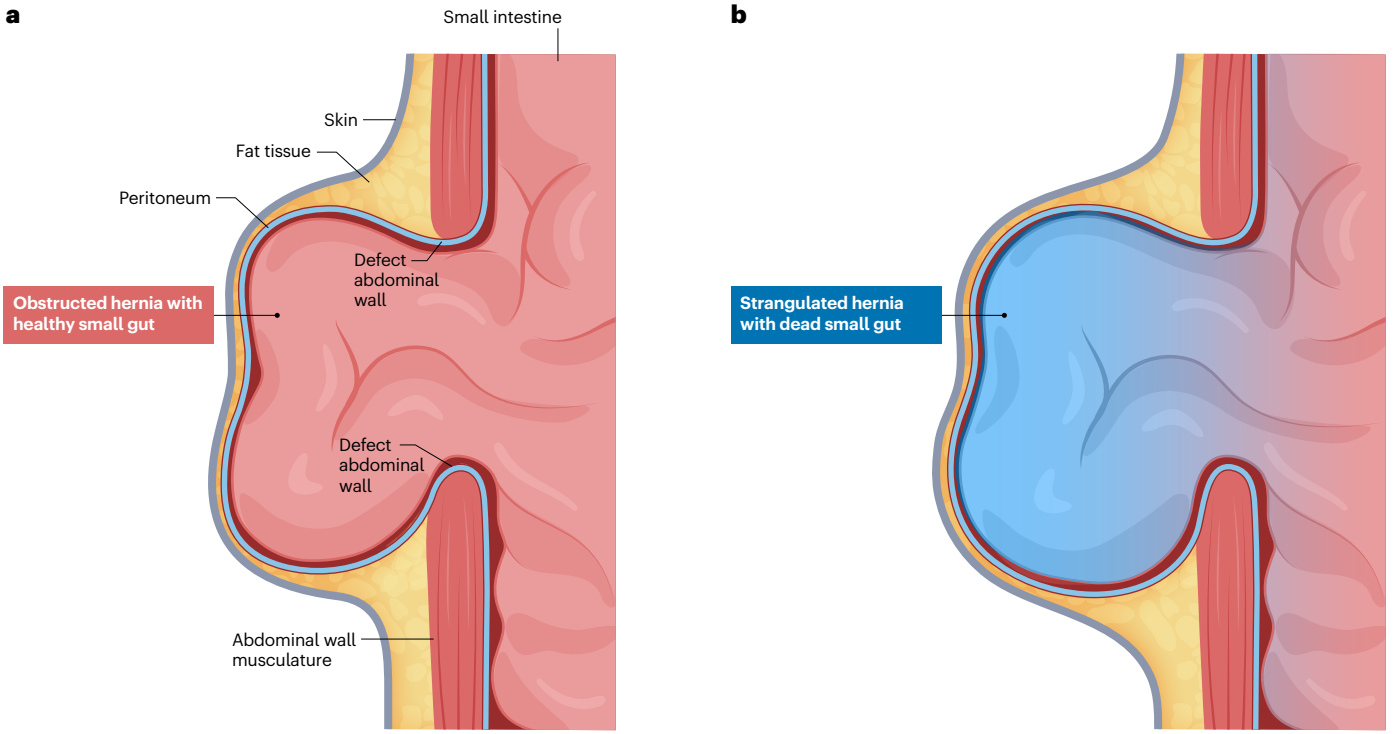

Fig. 3 | In strangulation, blood supply to the herniated tissue is compromised. In a strangulated hernia, the hernia content is necrotic because of the compromised blood supply. **a**, The patient presents with an irreducible, tender bulge in the groin area (side view). **b**, The small bowel is strangulated and, in later stages, the skin may become reddened.

in accordance with local protocols, may assist[79]. After reduction, surgical timing must be considered depending on the clinical condition and modifiable risk factors, and hospitalization may be recommended for observation, particularly if there is a risk of strangulation or recurrence, which may be high mainly for premature children – the earlier the birth, the higher the risk for strangulation and subsequent bowel resection[80].

Physical examination

Physical examination for suspected groin hernia should primarily be conducted with the patient standing upright as hernias are more likely to be visible in this position or when the patient coughs[6]. The typical method involves the surgeon sitting while the patient stands during the examination. Most hernias will have a cough impulse and change in size with straining. Additional information may be obtained by examining the patient in the supine position[73]. When the patient lies down, the hernia may reduce in size, and the abdominal wall defect can be more easily palpated. However, for groin hernias, the size of the defect is generally less important than for ventral hernias and does not significantly affect surgical planning. It is also important to assess whether the hernia is reducible or incarcerated, as the latter may alter the choice of operative technique. For example, there are large scrotal hernias with non-reducible fatty tissue that are best treated anteriorly, whereas scrotal hernias with easily reducible bowel contents can be treated very well laparoscopically.

A common misconception is that a suspected inguinal hernia must be diagnosed by inserting a finger into the scrotum and pressing upward towards the superficial inguinal ring. This method is obsolete as the procedure is not necessary to make the diagnosis of an inguinal hernia. Simple external palpation of the inguinal canal is sufficient for diagnosis. However, scrotal examination remains part of the physical assessment to ensure both testicles are in place and to rule out other pathologies in the region.

Imaging modalities

The differential diagnoses of groin swelling can be quite broad and commonly include lymph nodes, hydroceles and lipomas in addition to hernias[10,11]. Although physical examination is the cornerstone of hernia diagnosis, imaging may be useful when clinical findings are inconclusive, such as when dealing with an occult hernia or an atypical lump with a shape, location, or texture that differs from routine hernia findings. In 2021, an Australian study revealed that nearly half of the patients referred to a surgeon with clinically apparent inguinal hernias also underwent unnecessary groin ultrasounds[81]. Imaging should be reserved for cases where the clinical presentation is unclear and the surgeon is uncertain of the diagnosis.

Ultrasonography has the highest sensitivity and specificity for diagnosing inguinal hernias when compared with CT and MRI[71]. In some countries, surgeons may perform the ultrasound themselves, while in others, radiologists handle the imaging. Regardless of the method, it is essential that the operator has a solid understanding of hernia anatomy and disease.

Management

Inguinal hernia repair has seen significant improvements over the centuries, driven by a better understanding of the anatomy and mechanics of the inguinal canal and the pathophysiology of hernia formation

as well as improvements in surgical techniques. Historically, hernia treatment dates to ancient times with primitive methods ranging from observation and enemas to more invasive procedures such as resection and cauterization, often with hemicastration. The first recorded surgical repairs were documented in the Ebers papyrus in ancient Egypt around 1550 BC[82,83]. The modern era of inguinal hernia repair began in 1887, when Edoardo Bassini introduced his landmark tissue-based repair technique, which was built on modern anatomical principles and understanding of the inguinal canal[84]. Earle Shouldice refined the layered closure technique by distributing the tension over several overlapping tissue layers[85]. In the 1980s, Irving Lichtenstein popularized the open tension-free mesh-based repair, a breakthrough that significantly reduced recurrence rates and allowed for reliable and reproducible routine repairs that could be performed as outpatient ambulatory procedures[86,87]. Laparoscopic approaches, introduced later in the twentieth century, provided minimally invasive alternatives to traditional open surgery, offering patients less postoperative pain, quicker recovery times and lower risk of chronic pain[82,83]. These laparoscopic and robotic procedures repair the hernial defects in the inguinal canal from a posterior approach reinforcing the myopectineal orifice described by Henry Fruchaud, covering the direct, indirect and femoral canals with a mesh prosthesis placed in the preperitoneal space[10]. Today, inguinal hernia repair is one of the most common operations, with several safe and effective techniques[10]. The field continues to evolve with ongoing research, advances in prosthetics, refinement of techniques, the use of robotic platforms and evidence-based recommendations to standardize outcomes, reduce recurrence, minimize chronic pain and complications, and improve quality of life.

Conservative management

The conservative management of inguinal hernia is focused on symptom control and monitoring to balance the benefits of repair against the risk of surgery. In patients averse to surgery, older patients or those with significant comorbidities who may be at higher risk for surgical complications, expectant management can be employed with a focus on symptom management such as the use of a truss belt and modification of activity[88]. However, due to improvements in anaesthesia techniques, comorbidities are not such a great hindrance for general anaesthesia as some years ago, making more patients suitable for surgery than decades ago[89].

Watchful waiting. Watchful waiting refers to monitoring asymptomatic or minimally symptomatic inguinal hernias without immediate surgical intervention. Several studies have evaluated the safety and outcomes of watchful waiting versus early surgical repair[10,11,90,91]. Watchful waiting was associated with a low risk of progression to symptomatic hernia or complications requiring emergency surgery for incarceration or strangulation[91]. However, one-third of the patients crossed over to surgery after 3 years and two-thirds after 10 years, mainly owing to pain progression. These findings were supported by another 12-year follow-up study, which also indicated that most patients eventually opt in for surgery due to pain rather than the risk of strangulation[92]. Patients who consider surgery can be informed that it is generally safe to wait but that they are likely to require surgery within a few years, primarily to address symptoms rather than to avoid life-threatening complications. While watchful waiting may be suitable for selected patients, over a longer period of observation, most patients in this cohort will crossover to operative intervention as their hernias enlarge or become more symptomatic[91].

There is a general fear among patients and family doctors regarding the risk of acute strangulation in groin hernias[93]. However, the actual risk of incarceration and strangulation is very small, especially in men[94]. Proper patient education on the symptoms of strangulation significantly reduces this risk, making 'watchful waiting' a safe option for male patients. A systematic review that followed 858 male patients with inguinal hernia under a watchful waiting strategy found no increase in mortality, acute hernia-related operations or postoperative complications compared with those who underwent early surgery[91].

While watchful waiting has been found to be safe in otherwise healthy and asymptomatic male patients, it is not a validated or recommended option in female patients due to a higher rate of incarceration and strangulation[91]. Careful patient selection and regular monitoring are essential to detect any changes in hernia status and intervene if necessary.

Surgical management

Open repair techniques. Tissue repair techniques, such as the Bassini and Shouldice repairs, involve meticulous dissection and suturing of the weakened abdominal wall layers to reinforce the inguinal canal[84,85]. They remain viable options for inguinal hernia repair, particularly in settings where mesh may not be readily available. These techniques have demonstrated long-term durability and low recurrence rates, particularly in specialized centres with experienced surgeons[95]. Still, tissue repair is associated with higher rates of postoperative pain, longer recovery times and higher recurrence in general practice compared with mesh-based techniques[10,11].

The Bassini repair involves approximating the triple layer medially to the inguinal ligament laterally to reinforce the weakened direct space and dilated internal ring with interrupted sutures. The Shouldice technique is best understood as a technical refinement of the Bassini repair separating the closure of the inguinal floor and internal ring into four overlapping suture lines that distribute the tension and optimize the durability of the closure (Fig. 4). The Shouldice repair is highly effective when performed well in favourable patient cohorts with outcomes matching prosthetic based techniques and has been recommended in the 2023 HerniaSurge International Guidelines on groin hernia management as the best tissue repair[10,11,95]. The Desarda technique utilizing a pedicled flap of external oblique aponeurosis to buttress the inguinal floor has a shorter learning curve when compared with the Shouldice repair and is especially effective in low-resource settings[11,96]. More high-quality, long-term data on recurrence and chronic pain is needed for recommendations on adoption[11]. Tissue repair remains an important component of the surgical armamentarium for inguinal hernia management, especially for adolescents, small hernias, young and female patients at low risk, mesh-averse patients who fear mesh-related complications, resource-limited settings, and in contaminated fields owing to bowel perforation in strangulated hernias[10,11].

Open mesh repair techniques remain an effective, low-cost, safe and reproducible option in the treatment of inguinal hernia worldwide. The Lichtenstein technique, popularized by Irving Lichtenstein in the 1980s and refined by Dr Parviz Amid, is the best evaluated and most utilized open mesh-based technique and is the preferred open approach for inguinal hernia repair owing to its favourable outcomes, short learning curve and ability to be performed under local anaesthesia[86,87]. This technique involves placement of a synthetic mesh within the inguinal canal over the hernia defect and around the spermatic cord to provide a tension-free repair (Fig. 5). Given this ubiquity, the

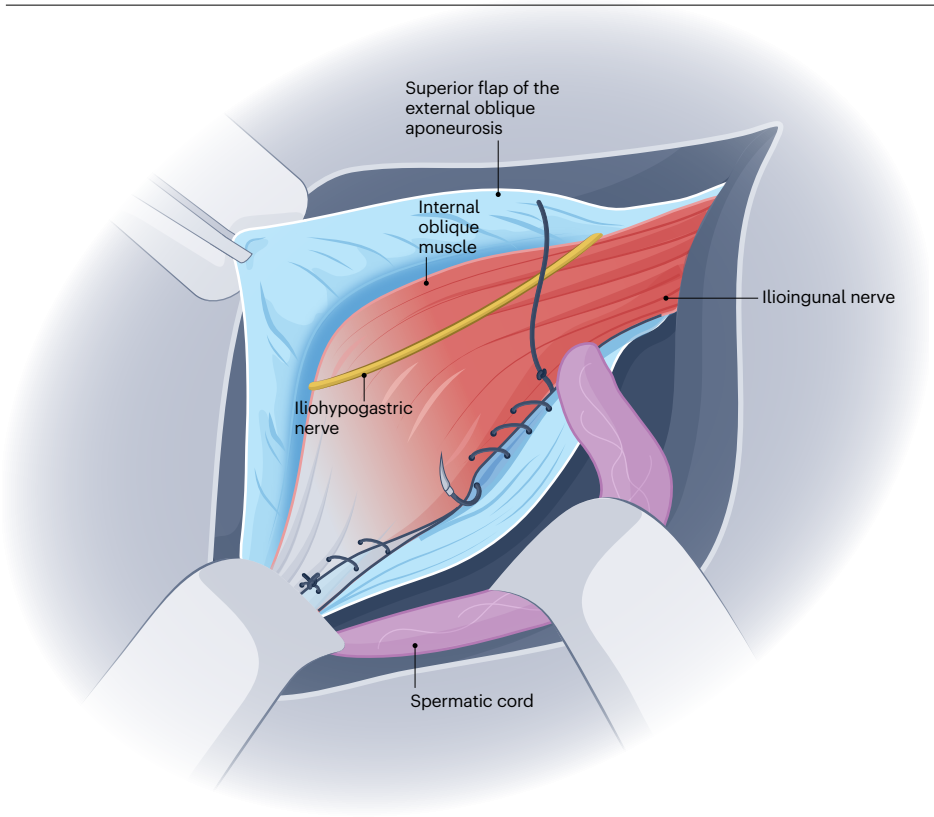

Fig. 4 | Shouldice repair. The Shouldice repair is a tension-free, multi-layered, continuous sutured reconstruction of the posterior inguinal wall using the transversalis fascia, internal oblique and transversus abdominis muscles, performed without mesh. Adapted with permission from ref. 156, Wiley.

Lichtenstein repair serves as the standard benchmark compared with all other inguinal repair techniques[10,11]. Open preperitoneal inguinal hernia repairs can be performed via a transinguinal, transrectus[97] or midline approach placing a mesh prosthesis in the preperitoneal plane[98]. The outcomes and results of open preperitoneal repair are at least equal to Lichtenstein repair, although the longer learning curve and required expertise have limited its adoption[11]. Numerous studies have demonstrated the safety and efficacy of open mesh repair, with meta-analyses and systemic reviews consistently reporting low rates of recurrence and complication making it the gold standard for open inguinal hernia repair[10,11].

Minimally invasive laparoscopic inguinal hernia repair. Minimally invasive laparoscopic inguinal hernia techniques were introduced in 1992 by Arregui et al.[99] (transabdominal preperitoneal (TAPP) technique) and in 1993 by KcKernan and Laws[100] (totally extraperitoneal (TEP) technique) and have matured to their current state as standardized, reproducible, reliable techniques[10,11,101]. The two primary laparoscopic techniques differ primarily in their approach to the preperitoneal space either accessing this as a TAPP or TEP repair. After complete dissection of the myopectineal orifice exposing the direct, indirect and femoral spaces to address all variants of groin hernia, a mesh prosthesis is placed in the preperitoneal space to reinforce the weakened abdominal wall[101]. When performed properly with sufficient expertise, laparoscopic inguinal hernia repair offers several advantages over open techniques, including smaller incisions, reduced postoperative pain, lower incidence of chronic pain and faster recovery times[60,66]. It also has the advantage of making bilateral repair possible through the same incisions and the diagnosis of a concomitant femoral repair owing to extensive dissection. Several meta-analyses and systematic reviews have demonstrated comparable outcomes between laparoscopic and open mesh repair, making it an attractive option for many patients. The 2023 HerniaSurge International Guidelines reaffirm the recommendation for a laparoscopic technique for patients with primary unilateral inguinal hernia provided that a surgeon with specific expertise and sufficient resources is available[11].

TAPP and TEP repair offer similar outcomes in terms of recurrence rates and postoperative complications[10,11]. However, the two technical approaches lead to different potential intra-operative and postoperative complications. TAPP involves entering the peritoneal cavity and creating a dissection plane between the peritoneum and the posterior inguinal wall, while TEP avoids entering the peritoneal cavity altogether by dissecting the extraperitoneal space. TAPP may increase the risk of intra-abdominal injuries such as bowel perforation or vascular injury[102]. The closure of the peritoneal flap carries a small risk of dehiscence leading to bowel obstruction and adhesions, and the transabdominal port placement carries a small risk of port site herniation[103,104]. By contrast, TEP repair potentially reduces the risk of intra-abdominal complications but requires advanced laparoscopic skills for extraperitoneal dissection and a more challenging learning curve for adoption and proficiency[102]. TEP may also carry higher operative costs if a dissecting balloon is used. No significant differences in outcomes and complications have been reported and the choice between TAPP and TEP repair should be individualized based on surgeon expertise, patient characteristics and institutional resources[10,11].

Robotic-assisted inguinal hernia repair. Robotic-assisted inguinal hernia repair is a relatively new approach that offers enhanced dexterity and visualization compared with traditional laparoscopy. The evidence supporting robotic inguinal hernia repair remains limited, with few studies comparing its outcomes to conventional laparoscopic techniques[105]. The results show that robotic-assisted repair offers comparable outcomes in terms of recurrence rates and postoperative complications but it is associated with increased operation time and treatment costs[105]. Fundamentally, robotic inguinal hernia repair is identical to laparoscopic TAPP repair and the differences are only a function of the tool used to accomplish the operation. The anticipated outcomes and principles of the operation remain the same. The greatest benefit of robotic repair has been to increase the adoption, proficiency and availability of minimally invasive inguinal hernia repair by enabling surgeons to overcome the challenging learning curve and helping to standardize the operation[105]. Robotic inguinal hernia repair is particularly beneficial for complex cases (such as recurrence or operating in the scarred re-operative field) and in patients with challenging anatomy (such as those with obesity, large hernias or visceral involvement) but its widespread adoption may be limited by high costs, resource availability and environmental sustainability.

Operative tailoring and selection. Patient selection for inguinal hernia repair varies based on factors such as patient age, sex, comorbidities, hernia size and surgeon preference. In resource-limited settings, watchful waiting may be more common due to constraints on health-care resources and access to surgical care[91]. Conversely, in high-resource countries, surgical repair is often recommended for symptomatic or enlarging hernias to prevent complications such as incarceration or strangulation and improve quality of life[10,11]. Female patients are recommended to undergo operative repair given the higher risk of incarceration and strangulation and a posterior mesh-based repair is recommended given the potential for a femoral hernia[11]. Patients with bilateral inguinal hernias are optimally served with a minimally invasive repair given that both sides can be repaired through the same operative approach. Young patients, female patients and those with small indirect hernias may be offered a tissue repair with favourable outcomes seen in this cohort[11]. Comorbid patients, for example, those with severe cardiac disease, who have an increased risk of general anaesthesia may be offered an open repair under local anaesthesia. Shared decision-making between patients and health-care providers is essential to tailor treatment plans based on individual circumstances and available resources. Additionally, disparities in health-care infrastructure and access to specialized care may influence the availability of certain surgical techniques, leading to variations in patient management across different regions.

Postoperative care. Several postoperative measures can improve outcomes and reduce the risk of complications following inguinal hernia repair. Patients are typically advised to immediately return to normal ambulation and aerobic activities[106]. While there is significant variation in practice, patients are often advised to avoid heavy lifting and strenuous activities for a short period to allow adequate healing of the surgical site[107]. In reality, the immediate strength of prosthetic-reinforced repairs exceeds the forces generated by most physical exertion and the pragmatic goal should be to minimize patient discomfort while promoting early progression to normal function. Pain

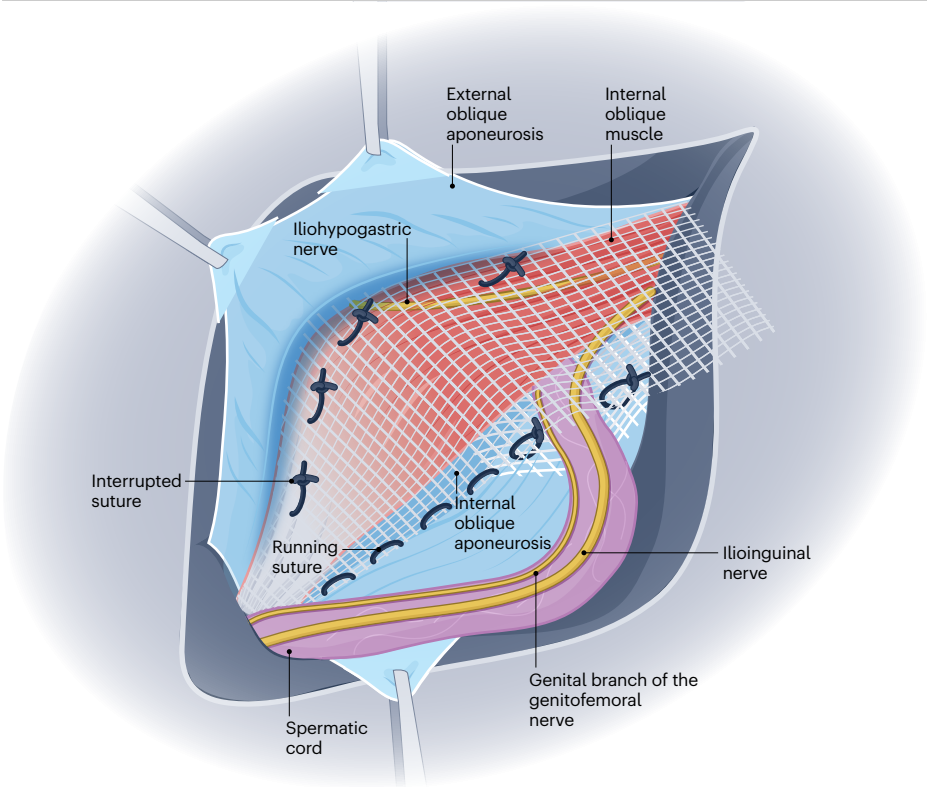

Fig. 5 | Amid-modified Lichtenstein repair. The Amid-modified Lichtenstein repair is a tension-free open inguinal hernia repair technique that involves placing a polypropylene mesh over the posterior wall of the inguinal canal, secured with sutures, to reinforce the defect and reduce recurrence rates. Adapted from ref. 157, Springer Nature Limited.

management strategies, including non-steroidal anti-inflammatory drugs, long-acting local anaesthetics and opioid-sparing techniques, can help alleviate discomfort while promoting early mobilization. Given the morbidity associated with the overuse of opioid-based medications[108], setting clear expectations and pre-operative counselling in the postoperative period both help to proactively balance patient comfort with minimal opioid usage. Follow-up in the postoperative period should be available to ensure proper wound healing, monitor for complications, and assess the efficacy of the repair and impact on quality of life.

Complications. Despite advancements and standardization in surgical techniques, inguinal hernia repair carries a risk of both early and late complications. Early complications may include mesh infection, mesh migration, visceral injury, bleeding, haematoma and seroma formation. Although serious adverse events are rare in modern hernia repair, the high procedural volume inevitably results in a subset of patients experiencing complications[10]. Mesh infection, while uncommon, remains a potentially serious issue that may necessitate antibiotic therapy, surgical intervention and, in some cases, mesh explantation. While mesh repair is widely considered the gold standard for many hernia types due to its effectiveness in reducing recurrence, postoperative complications, such as chronic pain and mesh-related adverse events, have led to patient complaints and an increasing number of legal actions[109,110]. These developments underscore the need for careful patient selection, thorough pre-operative counselling and long-term follow-up. Haematoma and seroma formation are more common and can usually be managed conservatively with observation or drainage if symptomatic[10]. Other less common acute complications include wound dehiscence, visceral injury, nerve injury and urinary retention. Prompt recognition and management of these complications are essential to minimize morbidity and optimize patient outcomes. The most relevant chronic complications include recurrence and chronic pain, both of which are central to patient outcomes and quality of life.

In the mesh era, the risk of recurrence has decreased dramatically, with most standardized techniques reporting a 2–3% overall recurrence rate in practice[111]. Risk factors for groin hernia recurrence include patient factors, such as obesity, smoking and chronic cough, as well as technical factors such as incomplete dissection, missed coexisting hernias, and inadequate mesh fixation or placement[112]. Suboptimal surgery remains the most important risk factor for recurrence. Management of recurrent hernias often involves revision surgery, with options including open or minimally invasive repair using mesh reinforcement[10]. In general, utilizing an unscarred alternate plane is advantageous for recurrent repair although re-operating in the same field may be chosen when expertise is available and there is a clinical benefit to re-entering the scarred plane[10]. Careful patient selection and meticulous surgical technique are crucial to minimize the risk of recurrence. Ongoing surveillance and follow-up are essential to detect recurrent hernias early and intervene promptly to prevent complications.

Chronic pain following inguinal hernia repair is a well-recognized complication that can significantly impact the quality of life of patients and is arguably the most important outcome in elective inguinal hernia repair. Depending on the definition used, the incidence ranges from 10% to 63%[10,11]. However, meaningful pain that limits the quality of life and requires intervention occurs in approximately 5% of patients, an enormous burden of disease when the volume of inguinal hernia repair is considered[10,11]. The aetiology of chronic pain is multifactorial and includes recurrence, nerve injury, mesh-related inflammation, meshoma, osteitis, musculoskeletal disruption, testicular compromise or pre-existing pain syndromes. Management strategies for chronic pain after inguinal hernia repair include pharmacological interventions, such as neuropathic pain medications and antidepressants, as well as non-pharmacological approaches such as physical therapy, cognitive behavioural therapy, and nerve blocks or ablation[11]. In cases refractory to conservative measures, surgical remediation including exploration, mesh removal and neurectomy may be considered[11]. The decision to pursue revision surgery should be made judiciously after thorough evaluation and discussion with the patient and is best performed by a hernia surgeon with expertise. In cases of chronic postoperative inguinal pain, multidisciplinary collaboration between surgeons, pain specialists and rehabilitation therapists is often necessary to optimize pain management and improve patient outcomes and quality of life.

Emergencies. Inguinal hernias can present as emergencies, particularly when incarcerated or strangulated, leading to compromised blood supply to the herniated contents. Prompt surgical intervention is essential to relieve incarceration or strangulation by placing the hernia content in the abdominal cavity, repairing the hernia defect and preventing potentially life-threatening complications such as bowel obstruction, ischaemia or perforation. Emergency hernia repair may involve open or minimally invasive laparoscopic techniques, depending on the patient's clinical condition and surgeon expertise[11]. In cases of bowel obstruction secondary to hernia incarceration, bowel decompression may be necessary before definitive surgical repair. The clinical priority in the setting of emergency groin hernia is to address the life-threatening issues of visceral compromise and sepsis with the secondary consideration of hernia repair. Once these issues have been addressed and stabilized, the timing of hernia repair and the safety and propriety of the operative approach and use of mesh can be balanced against the increased risk in this challenging cohort. Early recognition of acute hernia complications and timely intervention are critical to minimizing morbidity and mortality associated with emergency hernia presentations.

Inguinal hernia repair has undergone important evolution over time, with several surgical techniques and approaches available to clinicians. While open mesh repair remains the gold standard, when expertise and proficiency are available, laparoscopic and robotic techniques offer minimally invasive alternatives with comparable durability and improved functional and quality-of-life outcomes. Patient selection and surgical decision-making should be tailored to individual patient factors, institutional resources and surgeon expertise. Despite advancements in surgical techniques, acute and chronic complications remain concerns, highlighting the importance of careful peri-operative management, meticulous standardized operative technique and long-term follow-up. Collaborative efforts between clinicians, researchers and patients are essential to further refine inguinal hernia management and optimize patient outcomes in the future.

Paediatric groin hernia management

Inguinal hernia repair is one of the most common paediatric surgical procedures[113]. Almost all paediatric inguinal hernias are indirect, developing from a patent processus vaginalis. The optimal timing for surgery in preterm infants requires balancing the risk of incarceration with the risk of respiratory complications. In preterm infants, elective surgery after discharge from the first hospitalization is often advised[114,115].

The universal operative principle for infant hernia is no mesh[113]. It is usually an indirect hernia and the scar from non-mesh repair works sufficiently to close the defect. Open inguinal hernia repair remains the most common treatment strategy for children. However, the incidence of metachronous contralateral inguinal hernia following unilateral open repair is approximately 6%[116]. The need for routine contralateral exploration and closure of a patent processus vaginalis remains debated, with studies suggesting that 17 contralateral explorations are required to prevent 1 metachronous contralateral inguinal hernia[116].

The laparoscopic approach is increasingly being adopted due to its ability to inspect the contralateral groin without requiring an additional incision and exploration. The laparoscopic technique can be divided into extraperitoneal (with extraperitoneal suturing and a subcutaneous knot) and intraperitoneal (with intraperitoneal suturing) approaches[117]. Systematic reviews with meta-analysis outcomes indicate that both open and laparoscopic repairs show similar conclusions in terms of complications, recurrence rates and recovery times. However, the laparoscopic extraperitoneal approach may offer advantages in terms of shorter operation times and fewer complications compared with open surgery[118,119].

Quality of life

Hernia research has traditionally focused on disease-related outcomes such as hernia recurrences and post-surgery infections. However, patient-reported outcomes, including reports on their quality of life, are equally important[8].

With the introduction of mesh in groin hernia repairs, recurrence rates have decreased significantly[111]. However, some patients still experience chronic pain that can adversely affect their quality of life[120]. A Danish nationwide questionnaire study reported that 29% of patients experienced pain 1 year after inguinal hernia repair, with more than half of them reporting functional impairment resulting from pain[121]. International guidelines on groin hernia management indicate an incidence of postoperative pain of up to 12%, which tends to diminish over time[10]. Certain risk factors have been linked to chronic pain, including younger age, female sex, emergency operations, open repairs, high peri-operative pain and hernia recurrence[97]. These reports primarily rely on surgeon-reported outcomes; however, the usage of patient-reported outcome measures (PROMs) has provided a more comprehensive understanding of the impacts on quality of life[122,123].

The tools used to measure quality of life can be either generic, such as SF-36 (ref. 124) and SF-12 (ref. 125), or specific to hernia repair, preferred for more targeted assessments. These include the Carolinas Comfort Scale (CCS)[126], the Hernia-Related Quality-of-Life Survey (HerQLes)[127], the European Registry for Abdominal Wall Hernias Quality-of-Life (EuraHS QoL) scores[128], the Core Outcome Measures Index adapted for patients with hernia[129], the Inguinal Pain Questionnaire[130], the Brief Pain Inventory[131] and Hernia-Specific Quality of Life (HERQL)[132]. Each tool offers distinct insights into different aspects of patient discomfort, function and pain following surgery, depending on the context.

The CCS, one of the most widely used quality-of-life instruments, is a validated 23-question survey that uses a five-point scale to assess pain, the sensation of a foreign body (the patient can feel the implanted mesh) and mechanical impairment[126]. HerQLes, is a 12-point scale that assesses pain levels during various activities, ranging from mild to strenuous, including sexual activity[127]. The EuraHS QoL focuses on three key parameters: pain, movement restriction resulting from pain and cosmetic concerns[128]. The HERQL questionnaire, which was developed in Taiwan, comprises a 4-item summative pain score measuring pain and discomfort resulting from various strenuous activities (rest or mild, moderate, or heavy activities)[132]. While there is no consensus on the best tool for measuring the quality of life in patients with hernia, CCS, HerQLes and SF-36 are among the most frequently used, with CCS found to achieve an excellent response rate[133].

PROMs have added significant value compared with surgeon-reported outcomes and are becoming essential tools for guiding hernia surgery. For example, the GENDOLCAT study utilized three QoL instruments (BPI, SF-12 and Doleur Neurpathica 4) and found that the incidence of chronic postoperative pain syndrome dropped from 14% at 4 months to 4% at 2 years[134]. Similarly, the GENESIS study, which focused on patients from Asia and Europe, reported that 15% of patients had a CCS score higher than 25 at a 2-year follow-up[135]. Higher CCS scores were associated with emergency operations, open surgical approaches, and cases of recurrent hernias or surgical site infections[135]. Interestingly, the study found geographical variations, with patients undergoing elective open hernia repair in Europe reporting higher CCS scores than those in Asia[135]. However, these findings should be interpreted cautiously as they may reflect poor study design rather than the comparison between the procedures.

A study comparing open and laparoscopic preperitoneal approaches found no significant difference in quality-of-life outcomes reported by the CCS and EuraHS scales, suggesting that the surgical approach itself may not be as critical as the dissection plane used during surgery[136]. PROMs on quality of life are adding new data and the perspective of patients to research on groin hernia surgery and will potentially shape future clinical practice guidelines. However, standardized quality-of-life protocols and their validation are still required to reduce reporting heterogeneity[137,138].

Outlook

Despite clear advancements in groin hernia repair techniques, several critical gaps remain in the understanding of the aetiology and pathophysiology of hernias[34], such as a lack of clarity in the genetic predisposition to hernia formation for both primary hernia and recurrences. A convincing inheritance pattern exists in hernia disease[49], with multiple responsible genes identified[50,139]. Genetic research could uncover specific markers or familial patterns that make certain populations more susceptible, laying the groundwork for personalized treatment approaches in hernia care[140].

There remains a need for an ideal biomaterial for hernia meshes[141–143]. Although advances have been made in biodegradable meshes and surface coatings, our understanding of how various materials interact with human tissues – particularly in complex cases such as recurrent or infected hernias – remains limited. Despite the diversity in mesh materials and structures, no design has yet achieved the optimal balance between durability, biocompatibility, and the prevention of complications such as adhesions, infections and chronic pain. Further research is needed to assess the long-term effects of mesh implantation, including foreign body sensations. Future efforts should focus on engineering meshes that not only provide mechanical support but also promote tissue regeneration. Emerging technologies, such as 3D printing, growth factor integration and bioengineered scaffolds, may offer promising pathways towards meshes that enhance the body's natural healing processes.

In clinical research, the collection of long-term outcome data following hernia surgery remains insufficient. There is a continued need for high-quality, longitudinal studies that evaluate not only recurrence rates but also patient-centred outcomes such as chronic pain and

quality of life[144]. While many trials examine the efficacy of different mesh types, few explore alternative surgical techniques or assess how pre-operative and postoperative management strategies influence outcomes. A major research priority should be a stronger focus on patient-centred outcomes, particularly postoperative quality of life[8]. Hernia repair is primarily performed to enhance the quality of life, yet most comparative studies still emphasize traditional metrics like recurrence, infection and pain. Future studies should assess quality of life as a primary outcome rather than a secondary consideration[8]. In some cases, reported complications may be of limited relevance if patients are ultimately satisfied with the procedure and experience improvement in symptoms. To advance precision medicine[145] in hernia surgery, outcomes research must incorporate quality-of-life parameters across diverse patient groups, hernia types and repair techniques.

The lack of sufficient qualification of surgeons has been identified as a potential risk factor for chronic pain and hernia recurrences. To address this, additional training, surgical simulation and education in evidence-based practice have been widely recommended[146–148]. Despite growing attention to the quality of hernia treatment[149], sustained focus is essential. Technological advancements offer promising opportunities to enhance surgical education and standardize care. High-fidelity simulation platforms, virtual reality-based training modules and telementoring can facilitate skill acquisition and assessment in a safe, controlled environment. Furthermore, digital tools, such as video-based coaching, real-time intra-operative feedback systems and artificial intelligence-driven decision support, can help reduce variability in technique and improve adherence to best practices. Integrating these technologies into structured training pathways and certification processes may be key to improving long-term outcomes and minimizing complications in hernia repair across diverse health-care settings.

The development of more personalized approaches to hernia management is important. With genetic and biomarker research still in its infancy, efforts should focus on identifying groups at high risk for both primary hernias and recurrences. Results from large-scale longitudinal outcome studies based on prospective hernia registries, such as the Danish Hernia Database, Swedish Hernia Registry, Herniamed, EuraHS, Club Hernie, EVEREG and AHSQC[150], will hopefully establish which patients should receive which treatments for their hernia disease. Advances in genomics and proteomics could allow surgeons to tailor interventions based on individual patient risk factors, minimizing the risk of recurrence and optimizing long-term quality-of-life outcomes.

Long-term research priorities

Looking further ahead, the ultimate goal in hernia research is the development of fully regenerative repair techniques. One area that holds considerable promise is tissue engineering[151]. The ability to engineer abdominal wall tissues, complete with innervation and vascularization, could represent the future of hernia repair. While current technologies, like 3D printing and bioengineering, are still in the early stages, they offer exciting possibilities. The creation of scaffolds that not only support tissue but also induce new muscle, fascia, vascularity and nerve growth could revolutionize how we approach hernia repair[141,152].

Another long-term priority is the integration of surgical data science into practice. Future operating rooms may become highly digitized environments where real-time data from patients are analysed using artificial intelligence to guide surgical decisions. From pre-operative imaging and other sources of information to intra-operative navigation and postoperative recovery, data-driven decision-making could improve the precision and outcomes of hernia surgeries[153]. Artificial intelligence could assist surgeons in predicting complications, optimizing mesh placement and even automating parts of the surgical procedure.

Will there be a hernia pill one day?

The concept of a 'hernia pill' remains speculative but intriguing. If researchers can unlock the genetic or biochemical pathways responsible for hernia formation[154,155], pharmaceutical interventions may be developed to prevent or reverse the underlying causes. For example, if certain genetic mutations predispose individuals to weak connective tissue, a targeted medication could strengthen these tissues and reduce the likelihood of hernia formation. Understanding the precise molecular mechanisms involved in hernia development is the first step. Although we are far from this reality, advancements in molecular biology, genetics and tissue engineering could one day lead to treatments that prevent hernia formation altogether, making surgical interventions obsolete. Though this concept is still in the realm of science fiction, it is worth considering as a long-term research goal.

The future of groin hernia surgery is filled with possibilities. Addressing the outstanding gaps in basic, translational and clinical research will require a multidisciplinary approach, combining insights from geneticists, bioengineers, clinicians and surgeons. Over the next decade, priorities should focus on refining surgical techniques, improving biomaterials and advancing personalized medicine. As technology evolves, innovations in tissue engineering and surgical data science will likely transform the way hernia surgeries are performed, pushing the boundaries of what is possible. And, while the idea of a hernia pill may seem distant, it serves as a reminder that hernia research must continue to evolve in ways we can only begin to imagine. Ultimately, addressing these outstanding challenges through multidisciplinary research and collaboration will be important for continuing to improve the outcomes and quality of life for patients with hernia disease.

Published online: 03 July 2025

References

1. Inguinal hernia (groin hernia). *Cleveland Clinic* https://my.clevelandclinic.org/health/diseases/16266-inguinal-hernia (2022).
2. Inguinal hernia. *The British Hernia Centre* https://www.hernia.org/types/inguinal/ (2025).
3. Suzuki, S. et al. Differentiation of femoral versus inguinal hernia: CT findings. *AJR Am. J. Roentgenol.* **189**, W78–W83 (2007).
4. Hogan, S., Skanes, M. & Hartery, A. Groin hernias: a pictorial essay outlining basic anatomy with illustration of interesting cases on computed tomography. *SN Compr. Clin. Med.* **2**, 2738–2748 (2000).
5. Piga, E., Öberg, S., Andresen, K. & Rosenberg, J. Intraoperative handling of spermatic cord lipomas during inguinal hernia repair: a nationwide survey. *Hernia* **25**, 1331–1337 (2021).
6. Malangoni, M. A. & Rosen, M. J. in *Sabiston Textbook of Surgery* (eds Townsend, C. M. Jr. et al.) 1114–1140 (Elsevier, 2012).
7. Vad, M. V., Frost, P., Rosenberg, J., Andersen, J. H. & Svendsen, S. W. Inguinal hernia repair among men in relation to occupational mechanical exposures and lifestyle factors: a longitudinal study. *Occupat. Environ. Med.* **74**, 769–775 (2017).
8. Rosenberg, J., Gram-Hanssen, A., Reistrup, H. & Baker, J. J. Rethinking surgical success in benign disease — why patient experience must lead. *J. Patient. Rep. Outcomes* (in the press).
This paper explains a paradigm shift in surgical outcome assessment after hernia repair with a focus on PROMs rather than classical surgical measures such as recurrences or infections.
9. Bisgaard, T., Bay-Nielsen, M., Christensen, I. J. & Kehlet, H. Risk of recurrence 5 years or more after primary Lichtenstein mesh and sutured inguinal hernia repair. *Br. J. Surg.* **94**, 1038–1040 (2007).
10. HerniaSurge Group. International guidelines for groin hernia management. *Hernia* **22**, 1–165 (2018).
International guidelines paper covering numerous issues in groin hernia management.
11. Stabilini, C. et al. Update of the international HerniaSurge guidelines for groin hernia management. *BJS Open* **7**, zrad080 (2023).
Update of the HerniaSurge international guidelines on selected areas.

12. Abramson, J. H., Gofin, J., Hopp, C., Makler, A. & Epstein, L. M. The epidemiology of inguinal hernia. A survey in western Jerusalem. *J. Epidemiol. Community Health* **32**, 59–67 (1978).
13. Lomanto, D. et al. Inguinal hernia repair: toward Asian guidelines. *Asian J. Endosc. Surg.* **8**, 16–23 (2015).
14. Kingsnorth, A. & LeBlanc, K. Hernias: inguinal and incisional. *Lancet* **362**, 1561–1571 (2003).
15. Primatesta, P. & Goldacre, M. J. Inguinal hernia repair: incidence of elective and emergency surgery, readmission and mortality. *Int. J. Epidemiol.* **25**, 835–839 (1996).
16. Hernández-Irizarry, R. et al. Trends in emergent inguinal hernia surgery in Olmsted County, MN: a population-based study. *Hernia* **16**, 397–403 (2012).
17. Burcharth, J., Pedersen, M., Bisgaard, T., Pedersen, C. & Rosenberg, J. Nationwide prevalence of groin hernia repair. *PLoS ONE* **8**, e54367 (2013).
18. Ohene-Yeboah, M. et al. Some aspects of the epidemiology of external Hernias in Kumasi, Ghana. *Hernia* **13**, 529–532 (2009).
19. Carbonell, J. F. et al. Risk factors associated with inguinal hernias: a case control study. *Eur. J. Surg.* **159**, 481–486 (1993).
20. Russell, R. C. G., Williams, N. S. &Bulstrode, C. J. K. (eds). *Bailey & Love's Short Practice of Surgery* 23rd edition (Hodder Education Publishers, 2000).
21. Dabbas, N., Adams, K., Pearson, K. & Royle, G. Frequency of abdominal wall hernias: is classical teaching out of date? *JRSM Short Rep.* **2**, 5 (2011).
22. Ruhl, C. E. & Everhart, J. E. Risk factors for inguinal hernia among adults in the US population. *Am. J. Epidemiol.* **165**, 1154–1161 (2007).
23. Hernias: learn more – how are inguinal (groin) hernias treated in men? *Institute for Quality and Efficiency in Health Care* https://www.ncbi.nlm.nih.gov/books/NBK395555/ (2023).
24. Chang, S. J., Chen, J. Y., Hsu, C. K., Chuang, F. C. & Yang, S. S. The incidence of inguinal hernia and associated risk factors of incarceration in pediatric inguinal hernia: a nation-wide longitudinal population-based study. *Hernia* **20**, 559–563 (2016).
25. Olesen, C. S., Mortensen, L. Q., Öberg, S. & Rosenberg, J. Risk of incarceration in children with inguinal hernia: a systematic review. *Hernia* **23**, 245–254 (2019).
26. Quintas, M. L., Rodrigues, C. J., Jin, H. Y. & Rodrigues Junior, A. J. Age related changes in the elastic fiber system of the interfoveolar ligament. *Rev. Hosp. Clin. Fac. Med. Sao Paulo* **55**, 83–86 (2000).
27. van Wessem, K. J. P., Simons, M. P., Plaisier, P. W. & Lange, J. F. The etiology of indirect inguinal hernias: congenital and/or acquired? *Hernia* **7**, 76–79 (2003).
28. Nilsson, E. et al. Hernia surgery in a defined population: a prospective three year audit. *Eur. J. Surg.* **163**, 823–829 (1997).
29. Löfgren, J. et al. Prevalence of treated and untreated groin hernia in eastern Uganda. *Br. J. Surg.* **101**, 728–734 (2014).
30. Grimes, C. E., Law, R. S. L., Borgstein, E. S., Mkandawire, N. C. & Lavy, C. B. D. Systematic review of met and unmet need of surgical disease in rural sub-Saharan Africa. *World J. Surg.* **36**, 8–23 (2012).
31. Gyedu, A. et al. Population-based rates of hernia surgery in Ghana. *Hernia* **24**, 617–623 (2020).
32. Statistics explained. Surgical operations and procedures statistics. *EuroStat* https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Surgical_operations_and_procedures_statistics#Number_of_surgical_operations_and_procedures (2024).
33. Rutkow, I. M. Demographic and socioeconomic aspects of hernia repair in the United States in 2003. *Surg. Clin. North Am.* **83**, 1045–1051 (2003).
34. Öberg, S., Andresen, K. & Rosenberg, J. Etiology of inguinal hernias: a comprehensive review. *Front. Surg.* **4**, 52 (2017).
35. Cowan, B. et al. Risk factors for inguinal hernia repair among US adults. *Hernia* **27**, 1507–1514 (2023).
36. Rosemar, A., Angerås, U. & Rosengren, A. Body mass index and groin hernia: a 34-year follow-up study in Swedish men. *Ann. Surg.* **247**, 1064–1068 (2008).
37. Abrahamson, J. Etiology and pathophysiology of primary and recurrent groin hernia formation. *Surg. Clin. North Am.* **78**, 953–972 (1998).
38. Leganger, J., Fonnes, S., Søborg, M. L. K., Rosenberg, J. & Burcharth, J. The most common comorbidities in patients with Ehlers-Danlos syndrome: a 15-year nationwide population-based cohort study. *Disabil. Rehabil.* **44**, 189–193 (2022).
39. Zendejas, B. et al. Relationship between body mass index and the incidence of inguinal hernia repairs: a population-based study in Olmsted County, MN. *Hernia* **18**, 283–288 (2014).
40. Addington, W. R., Stephens, R. E., Phelipa, M. M., Widdicombe, J. G. & Ockey, R. R. Intra-abdominal pressures during voluntary and reflex cough. *Cough* **4**, 2 (2008).
41. Pleumeekers, H. J., De Gruijl, A., Hofman, A., van Beek, A. J. & Hoes, A. W. Prevalence of aortic aneurysm in men with a history of inguinal hernia repair. *Br. J. Surg.* **86**, 1155–1158 (1999).
42. Henriksen, N. A., Sorensen, L. T., Jorgensen, L. N. & Lindholt, J. S. Lack of association between inguinal hernia and abdominal aortic aneurysm in a population-based male cohort. *Br. J. Surg.* **100**, 1478–1482 (2013).
43. Alder, R., Zetner, D. & Rosenberg, J. Incidence of inguinal hernia after radical prostatectomy: a systematic review and meta-analysis. *J. Urol.* **203**, 265–274 (2020).
44. Arnbjörnsson, E. Development of right inguinal hernia after appendectomy. *Am. J. Surg.* **143**, 174–175 (1982).
45. Lau, H., Fang, C., Yuen, W. K. & Patil, N. G. Risk factors for inguinal hernia in adult males: a case-control study. *Surgery* **141**, 262–266 (2007).
46. Liem, M. S., van der Graaf, Y., Zwart, R. C., Geurts, I. & van Vroonhoven, T. J. Risk factors for inguinal hernia in women: a case-control study. The Coala Trial Group. *Am. J. Epidemiol.* **146**, 721–726 (1997).
47. Marshall, A. G., Hutchinson, E. O. & Honisett, J. Heredity in common diseases. A retrospective survey of twins in a hospital population. *Br. Med. J.* **1**, 1–6 (1962).
48. Bakwin, H. Indirect inguinal hernia in twins. *J. Pediatr. Surg.* **6**, 165–168 (1971).
49. Öberg, S., Saeter, A. H. & Rosenberg, J. The inheritance of groin hernias: an updated systematic review with meta-analyses. *Hernia* **27**, 1339–1350 (2023).
50. Choquet, H. et al. Ancestry- and sex-specific effects underlying inguinal hernia susceptibility identified in a multiethnic genome-wide association study meta-analysis. *Hum. Mol. Genet.* **31**, 2279–2293 (2022).
51. Amro, C. et al. Genetic and biologic risk factors associated with hernia formation: a review. *Am. J. Surg.* **234**, 41–57 (2024).
52. Flich, J., Alfonso, J. L., Delgado, F., Prado, M. J. & Cortina, P. Inguinal hernia and certain risk factors. *Eur. J. Epidemiol.* **8**, 277–282 (1992).
53. Mamtani, R. & Cimino, J. A. Work related diseases among sanitation workers of New York City. *J. Environ. Health* **55**, 27–29 (1992).
54. Vad, M. V., Frost, P., Bay-Nielsen, M. & Svendsen, S. W. Impact of occupational mechanical exposures on risk of lateral and medial inguinal hernia requiring surgical repair. *Occup. Environ. Med.* **69**, 802–809 (2012).
55. Sarosi, G. A. et al. A clinician's guide to patient selection for watchful waiting management of inguinal hernia. *Ann. Surg.* **253**, 605–610 (2011).
56. Sæter, A. H., Fonnes, S., Rosenberg, J. & Andresen, K. Mortality after emergency versus elective groin hernia repair: a systematic review and meta-analysis. *Surg. Endosc.* **36**, 7961–7973 (2022).
57. Avisse, C., Delattre, J. F. & Flament, J. B. The inguinal rings. *Surg. Clin. North Am.* **80**, 49–69 (2000).
58. McArdle, G. C. Is inguinal hernia a defect in human evolution and would this insight improve methods of surgical repair? *Clin. Anat.* **10**, 47–55 (1997).
59. Skandalakis, L. J., Androulakis, J., Colborn, G. L. & Skandalakis, J. E. Obturator hernia. Embryology, anatomy, surgical applications. *Surg. Clin. North Am.* **80**, 71–84 (2000).
60. Dickinson, K. J., Thomas, M., Fawole, A. S., Lyndon, P. J. & White, C. M. Predicting chronic post-operative pain following laparoscopic inguinal hernia repair. *Hernia* **12**, 597–601 (2008).
61. Andresen, K. & Rosenberg, J. Management of chronic pain after hernia repair. *J. Pain Res.* **11**, 675–681 (2018).
62. Haastrup, E., Andresen, K. & Rosenberg, J. Low reoperation rates in young males after sutured repair of indirect inguinal hernia: arguments for a tailored approach. *Am. J. Surg.* **214**, 844–848 (2017).
63. Reistrup, H., Fonnes, S. & Rosenberg, J. No reason to use mesh in groin hernia repair in adolescents. *J. Abdom. Wall Surg.* **2**, 12336 (2024).
64. Pawlak, M., East, B. & de Beaux, A. C. Algorithm for management of an incarcerated inguinal hernia in the emergency settings with manual reduction. Taxis, the technique and its safety. *Hernia* **25**, 1253–1258 (2021).
65. Birindelli, A. et al. 2017 update of the WSES guidelines for emergency repair of complicated abdominal wall hernias. *World J. Emerg. Surg.* **12**, 37 (2017).
International guidelines on emergency repair.
66. Liu, J. et al. If laparoscopic technique can be used for treatment of acutely incarcerated/strangulated inguinal hernia? *World J. Emerg. Surg.* **16**, 5 (2021).
67. Pastorino, A. & Alshuqayfi, A. A. *Strangulated Hernia* (StatPearls, 2022).
68. Scallan, J., Huxley, V. H. & Korthuis, R. J. In *Capillary Fluid Exchange: Regulation, Functions, and Pathology* Ch. 4 (Morgan & Claypool Life Sciences, 2010).
69. Yang, X. F. & Liu, J. L. Acute incarcerated external abdominal hernia. *Ann. Transl. Med.* **2**, 110 (2014).
70. Sepsis and perforated bowel. *Sepsis Alliance* https://www.sepsis.org/sepsisand/perforated-bowel/ (2024).
71. Piga, E., Zetner, D., Andresen, K. & Rosenberg, J. Imaging modalities for inguinal hernia diagnosis: a systematic review. *Hernia* **24**, 917–926 (2020).
72. Goethals, A., Azmat, C. E., Patel, P. J. & Adams, C. T. *Femoral Hernia* (StatPearls Publishing, 2025).
73. Sogunro, O. A. How to examine the inguinal region. *Med Mastery* https://www.medmastery.com/guides/abdominal-examination-clinical-guide/how-examine-inguinal-region (2021).
74. Schizas, D. et al. Obturator hernias: a systematic review of the literature. *Hernia* **25**, 193–204 (2021).
75. Yale, S. H., Tekiner, H. & Yale, E. S. Role of the signs of obturator hernia in clinical practice. *Hernia* **25**, 235–236 (2021).
76. Inguinal hernia in babies. *Cleveland Clinic* https://my.clevelandclinic.org/health/diseases/4337-inguinal-hernia-treatment-for-children (2022).
77. Chen, J., Shen, Y., Chu, C., Zou, Z. & Yuan, X. in *The Art of Hernia Surgery* (ed Campanelli, G.) 187–197 (Springer International, 2018).
78. Skoog, S. J. & Conlin, M. J. Pediatric hernias and hydroceles. The urologist's perspective. *Urol. Clin. North Am.* **22**, 119–130 (1995).
79. Goldman, R. D., Balasubramanian, S., Wales, P. & Mace, S. E. Pediatric surgeons and pediatric emergency physicians' attitudes towards analgesia and sedation for incarcerated inguinal hernia reduction. *J. Pain* **6**, 650–655 (2005).
80. Peace, A. E. et al. Costs and recurrence of inguinal hernia repair in premature infants during neonatal admission. *J. Pediatr. Surg.* **58**, 445–452 (2023).
81. Naidoo, P. et al. How often are patients with clinically apparent inguinal hernias referred to a surgeon accompanied with an ultrasound? A prospective multicentre study. *Aust. Health Rev.* **45**, 36–41 (2021).
82. Basile, F., Biondi, A. & Donati, M. Surgical approach to abdominal wall defects: history and new trends. *Int. J. Surg.* **11**, S20–S23 (2013).

83. Sachs, M., Damm, M. & Encke, A. Historical evolution of inguinal hernia repair. *World J. Surg.* **21**, 218–222 (1997).
84. Read, R. C. The centenary of Bassini's contribution to inguinal herniorrhaphy. *Am. J. Surg.* **153**, 324–326 (1987).
Paper about the Bassini repair technique.
85. Shouldice, E. B. The Shouldice repair for groin hernias. *Surg. Clin. North Am.* **83**, 1163–1187 (2003).
Paper about the Shouldice repair technique.
86. Lichtenstein, I. L., Shulman, A. G., Amid, P. K. & Montllor, M. M. The tension-free hernioplasty. *Am. J. Surg.* **157**, 188–193 (1989).
Paper about the Lichtenstein repair technique.
87. Amid, P. K., Shulman, A. G. & Lichtenstein, I. L. Critical scrutiny of the open "tension-free" hernioplasty. *Am. J. Surg.* **165**, 369–371 (1993).
88. Whitaker, J., Akritidis, G. & Baker, D. Who's trusting in a truss? *Hernia* **18**, 147–148 (2014).
89. Fuchs-Buder, T. & Rosenberg, J. Medical disease and ambulatory surgery, new insights in patient selection based on medical disease. *Curr. Opin. Anesthesiol.* **35**, 385–391 (2022).
90. Fitzgibbons, R. J. Jr. et al. Watchful waiting vs repair of inguinal hernia in minimally symptomatic men: a randomized clinical trial. *JAMA* **295**, 285–292 (2006).
91. Reistrup, H., Fonnes, S. & Rosenberg, J. Watchful waiting vs repair for asymptomatic or minimally symptomatic inguinal hernia in men: a systematic review. *Hernia* **25**, 1121–1128 (2021).
92. Van den Dop, L. M. et al. Twelve-year outcomes of watchful waiting versus surgery of mildly symptomatic or asymptomatic inguinal hernia in men aged 50 years and older: a randomised controlled trial. *eClinicalMedicine* **64**, 102207 (2023).
93. Uzzaman, M. M. et al. Evaluation of patient's understanding and recall of the consent process after open inguinal hernia repairs. *Int. J. Surg.* **10**, 5–10 (2012).
94. Gallegos, N. C., Dawson, J., Jarvis, M. & Hobsley, M. Risk of strangulation in groin hernias. *Br. J. Surg.* **78**, 1171–1173 (1991).
95. Köckerling, F. et al. Has Shouldice repair in a selected group of patients with inguinal hernia comparable results to Lichtenstein, TEP and TAPP techniques? *World J. Surg.* **42**, 2001–2010 (2018).
96. Mohamedahmed, A. Y. Y., Ahmad, H., Abdelmabod, A. A. N. & Sillah, A. K. Non-mesh Desarda technique versus standard mesh-based Lichtenstein technique for inguinal hernia repair: a systematic review and meta-analysis. *World J. Surg.* **44**, 3312–3321 (2020).
97. Hajibandeh, S. et al. Meta-analysis of the outcomes of trans rectus sheath extra-peritoneal procedure (TREPP) for inguinal hernia. *Hernia* **26**, 989–997 (2022).
98. Andresen, K. & Rosenberg, J. Open preperitoneal groin hernia repair with mesh: a qualitative systematic review. *Am. J. Surg.* **213**, 1153–1159 (2017).
99. Arregui, M. E., Davis, C. J., Yucel, O. & Nagan, R. F. Laparoscopic mesh repair of inguinal hernia using a preperitoneal approach: a preliminary report. *Surg. Laparosc. Endosc.* **2**, 53–58 (1992).
Paper about the TAPP repair technique.
100. McKernan, J. B. & Laws, H. L. Laparoscopic repair of inguinal hernias using a totally extraperitoneal prosthetic approach. *Surg. Endosc.* **7**, 26–28 (1993).
Paper about the TEP repair technique.
101. Daes, J. & Felix, E. Critical View of the myopectineal orifice. *Ann. Surg.* **266**, e1–e2 (2017).
102. Andresen, K. & Rosenberg, J. Transabdominal pre-peritoneal (TAPP) versus totally extraperitoneal (TEP) laparoscopic techniques for inguinal hernia repair. *Cochrane Database Syst. Rev.* **7**, CD004703 (2024).
Cochrane review of TAPP versus TEP technique.
103. Wang, L. et al. Bowel obstruction and perforation secondary to barbed suture after minimally invasive inguinal hernia repair: report of two cases and literature review. *Surg. Case Rep.* **7**, 161 (2021).
104. Helgstrand, F., Rosenberg, J. & Bisgaard, T. Trocar site hernia after laparoscopic surgery: a qualitative systematic review. *Hernia* **15**, 113–121 (2011).
105. Li, X., Li, Y. J., Dong, H., Wang, D. C. & Wei, J. Meta-analysis of the effectiveness and safety of robotic-assisted versus laparoscopic transabdominal preperitoneal repair for inguinal hernia. *PLoS ONE* **19**, e0298989 (2024).
106. Rosenberg, J. et al. Non-operative considerations in relation to groin and ventral hernia repair: local consensus recommendations from the Danish Hernia Database. *Hernia* **29**, 186 (2025).
107. Harmankaya, S., Öberg, S. & Rosenberg, J. Varying convalescence recommendations for sport and heavy lifting after groin hernia repair: a nationwide survey among leading hernia surgeons. *Surg. Endosc.* **37**, 4443–4448 (2023).
108. Howard, R. et al. New persistent opioid use after inguinal hernia repair. *Ann. Surg.* **276**, e577–e583 (2022).
109. Eason, A., McDougall, H., Ganesh, A., Neal, D. & Al-Mansour, M. R. Hernia mesh and social media: misinformation, legal solicitation, and conflict of interest. *Surg. Endosc.* **39**, 554–559 (2025).
110. Holzheimer, R. G. & Hakim, N. The impact of social media on public perception and litigation in hernia surgery complications: a narrative review. *Complications* **1**, 51–60 (2024).
111. EU Hernia Trialists Collaboration.Repair of groin hernia with synthetic mesh: meta-analysis of randomized controlled trials. *Ann. Surg.* **235**, 322–332 (2022).
112. Gopal, S. V. & Warrier, A. Recurrence after groin hernia repair-revisited. *Int. J. Surg.* **11**, 374–377 (2013).
113. Pediatric inguinal and femoral groin hernia repair. *American College of Surgeons* https://www.facs.org/for-patients/the-day-of-your-surgery/pediatric-inguinal-and-femoral-groin-hernia-repair/ (2025).
114. Sacks, M. A. et al. Optimal timing of inguinal hernia repair in premature infants: a NSQIP-P study. *J. Surg. Res.* **283**, 690–698 (2023).
115. Choo, C. S., Chen, Y. & McHoney, M. Delayed versus early repair of inguinal hernia in preterm infants: a systematic review and meta-analysis. *J. Pediatr. Surg.* **57**, 527–533 (2022).
116. Staerkle, R. F. et al. Is it worth to explore the contralateral side in unilateral childhood inguinal hernia?: a PRISMA-compliant meta-analysis. *Medicine* **99**, e21501 (2020).
117. Morini, F. et al. Surgical management of pediatric inguinal hernia: a systematic review and guideline from the European Pediatric Surgeons' Association Evidence and Guideline Committee. *Eur. J. Pediatr. Surg.* **32**, 219–232 (2022).
118. Dreuning, K., Maat, S., Twisk, J., van Heurn, E. & Derikx, J. Laparoscopic versus open pediatric inguinal hernia repair: state-of-the-art comparison and future perspectives from a meta-analysis. *Surg. Endosc.* **33**, 3177–3191 (2019).
119. Zhao, J. et al. Laparoscopic versus open inguinal hernia repair in children: a systematic review. *J. Minim. Access. Surg.* **18**, 12–19 (2022).
120. Kehlet, H. Chronic pain after groin hernia repair. *Br. J. Surg.* **95**, 135–136 (2008).
121. Bay-Nielsen, M., Perkins, F. M., Kehlet, H. & Danish Hernia Database. Pain and functional impairment 1 year after inguinal herniorrhaphy: a nationwide questionnaire study. *Ann. Surg.* **233**, 1–7 (2001).
122. Manangi, M., Shivashankar, S. & Vijayakumar, A. Chronic pain after inguinal hernia repair. *Int. Sch. Res. Notices* **2014**, 839681 (2014).
123. Koning, G. G., Wetterslev, J., van Laarhoven, C. J. & Keus, F. The totally extraperitoneal method versus Lichtenstein's technique for inguinal hernia repair: a systematic review with meta-analyses and trial sequential analyses of randomized clinical trials. *PLoS ONE* **8**, e52599 (2013).
124. Ware, J. E. Jr. & Sherbourne, C. D. The MOS 36-Item Short-Form Health Survey (SF-36): I. Conceptual framework and item selection. *Med. Care* **30**, 473–483 (1992).
125. Ware, J. Jr., Kosinski, M. & Keller, S. D. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. *Med. Care* **34**, 220–233 (1996).
126. Heniford, B. T. et al. Comparison of generic versus specific quality-of-life scales for mesh hernia repairs. *J. Am. Coll. Surg.* **206**, 638–644 (2008).
127. Krpata, D. et al. Design and initial implementation of HerQLes: a hernia-related quality-of-life survey to assess abdominal wall function. *J. Am. Coll. Surg.* **215**, 635–642 (2012).
128. Muysoms, F. et al. EuraHS: The development of an international online platform for registration and outcome measurement of ventral abdominal wall hernia repair. *Hernia* **16**, 239–250 (2012).
129. Staerkle, R. & Villiger, P. Simple questionnaire for assessing core outcomes in inguinal hernia repair. *Br. J. Surg.* **98**, 148–155 (2011).
130. Fränneby, U. et al. Validation of an inguinal pain questionnaire for assessment of chronic pain after groin hernia repair. *Br. J. Surg.* **95**, 488–493 (2008).
131. Chung, L. & O'Dwyer, P. J. Pain and its effects on physical activity and quality of life before operation in patients undergoing elective inguinal and ventral hernia repair. *Am. J. Surg.* **208**, 406–411 (2014).
132. Huang, C. S., Tai, F. C., Lien, H. H., Wong, J. U. & Huang, C. C. Long-term follow-up of patients with hernia using the hernia-specific quality-of-life mobile app: feasibility questionnaire study. *JMIR Form. Res.* **6**, e39759 (2022).
133. Heniford, B. T. et al. Carolinas Comfort Scale as a measure of hernia repair quality of life: a reappraisal utilizing 3788 international patients. *Ann. Surg.* **267**, 171–176 (2018).
134. Bande, D., Moltó, L., Pereira, J. A. & Montes, A. Chronic pain after groin hernia repair: pain characteristics and impact on quality of life. *BMC Surg.* **20**, 147 (2020).
135. Baig, S., Sheth, H., Viswanath, N. G. & Madhok, B.; GENESIS Collaborative Group. Patient-reported outcomes in inguinal hernia surgery-Results from the GENESIS study: a multinational multicenter study. *World J. Surg.* **48**, 1132–1138 (2024).
136. Corthals, S. et al. Quality of life after open versus laparoscopic preperitoneal mesh repair for unilateral inguinal hernias. *Asian J. Surg.* **44**, 1266–1273 (2021).
137. Gram-Hanssen, A., Christophersen, C. & Rosenberg, J. Results from patient-reported outcome measures are inconsistently reported in inguinal hernia trials: a systematic review. *Hernia* **26**, 687–699 (2022).
138. Gram-Hanssen, A., Tolstrup, A., Zetner, D. & Rosenberg, J. Patient-reported outcome measures for inguinal hernia repair are insufficiently validated: a systematic review. *Int. J. Qual. Health Care* **32**, 223–230 (2020).
139. Fadista, J. et al. Comprehensive genome-wide association study of different forms of hernia identifies more than 80 associated loci. *Nat. Commun.* **13**, 3200 (2022).
140. Anyalebechi, J. C. & Davis, S. S. Jr. A personalized evolution in hernia care. *JAMA Surg.* **159**, 659 (2024).
141. Kalaba, S. et al. Design strategies and applications of biomaterials and devices for hernia repair. *Bioact. Mater.* **1**, 2–17 (2016).
142. Rodríguez, M., Gómez-Gil, V., Pérez-Köhler, B., Pascual, G. & Bellón, J. M. Polymer hernia repair materials: adapting to patient needs and surgical techniques. *Materials* **14**, 2790 (2021).
143. Corduas, F., Lamprou, D. A. & Mancuso, E. Next-generation surgical meshes for drug delivery and tissue engineering applications: materials, design and emerging manufacturing technologies. *Biodes. Manuf.* **4**, 278–310 (2021).
144. Gram-Hanssen, A., Baker, J. J., Reistrup, H., Andersen, K. K. & Rosenberg, J. Protocol for the AFTERHERNIA Project: patient-reported outcomes of groin and ventral hernia repair. *Hernia* **29**, 79 (2025).
145. Jameson, J. L. & Longo, D. L. Precision medicine-personalized, problematic, and promising. *N. Engl. J. Med.* **372**, 2229–2234 (2015).

146. Lange, J. F. et al. The role of surgical expertise with regard to chronic postoperative inguinal pain (CPIP) after Lichtenstein correction of inguinal hernia: a systematic review. *Hernia* **20**, 349–356 (2016).
147. Köckerling, F. What is the influence of simulation-based training courses, the learning curve, supervision, and surgeon volume on the outcome in hernia repair?-a systematic review. *Front. Surg.* **5**, 57 (2018).
148. Ndong, A. et al. Knowledge and practices regarding chronic pain after groin hernia surgery: a national resident survey in Senegal. *J. Abdom. Wall Surg.* **4**, 13764 (2025).
149. Rosenberg, J. Growing focus on hernia surgery. *Laparosc. Surg.* **4**, 35 (2020).
150. Kyle-Leinhase, I. et al. Comparison of hernia registries: the CORE project. *Hernia* **22**, 561–575 (2018).
An overview of the national and international hernia registries.
151. Altomare, M. et al. Regenerative medicine to improve outcomes of ventral hernia reconstruction (repair study) phase 1: find the best decellularization protocol for the human dermis. *J. Pers. Med.* **12**, 1411 (2022).
152. Zhang, L., Li, Q., Qin, J. & Gu, Y. Musculature tissue engineering to repair abdominal wall hernia. *Artif. Organs* **36**, 348–352 (2012).
153. Vedula, S. S. & Hager, G. D. Surgical data science: the new knowledge domain. *Innov. Surg. Sci.* **2**, 109–121 (2017).
154. Ahmed, W. U. et al. Shared genetic architecture of hernias: a genome-wide association study with multivariable meta-analysis of multiple hernia phenotypes. *PLoS ONE* **17**, e0272261 (2022).
155. Franz, M. G. The biology of hernia formation. *Surg. Clin. North Am.* **88**, 1–15 (2008).
156. Shouldice, E. B. The Shouldice natural tissue repair for inguinal hernia. *BJU Int.* **105**, 428–439 (2010).
157. Chen, D. C. & Amid, P. K. in *The SAGES Manual of Hernia Repair* (eds Jacob, B. P. & Ramshaw, B.) 41–54 (Springer, 2013).

Acknowledgements
The authors thank M. Singh, Consultant Surgeon, Indus Jaipur Hospital, Jaipur, India, for conducting the literature search for the chapter on epidemiology.

Author contributions
Introduction (J.R.); Epidemiology (S.B.); Mechanisms (J.D.); Diagnosis, screening and prevention (J.R.); Management (D.C.C. and J.D.); Quality of life (S.B. and J.D.); Outlook (J.R.); overview of the Primer (J.R.).

Competing interests
The authors declare no competing interests.

Additional information
Peer review information *Nature Reviews Disease Primers* thanks U. Dietz, U. Klinge, F. Malcher, G. Sandblom, D. Telem and the other, anonymous, reviewer(s) for their contribution to the peer review of this work.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.

© Springer Nature Limited 2025